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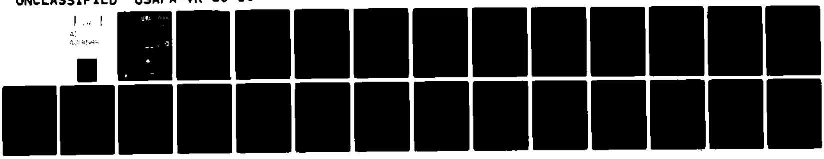

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# PROCESSING OF SEQUENTIAL AND HOLISTIC STIMULI IN LEFT AND RIGHT VISUAL FIELDS

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The two halves of the brain differ in their functional capabilities. This research project evaluates the ability of the two sides of the brain to process information presented in the visual periphery. Visual stimuli requiring parallel and serial processing were viewed parafoveally. The subjects were required to respond using either a manual response button or a bite switch. The data show that the response mode affects which processing style is used which in turn determines which half of the brain is used to process the

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information. The data suggest that with the bite-switch response mode stimuli presented in the right visual field are processed more rapidly and accurately than in the left field. With a manual response, the opposite field effects were seen. The data are discussed as they relate to visual processing in complex work environments, such as aircraft cockpits.

TABLE OF CONTENTS

LIST OF FIGURES

## LIST OF TABLES

# SECTION I

# INTRODUCTION

## PREVIOUS RESEARCH

In an increasingly technical Air Force, man is becoming the "weak link" in the man/machine interface. Jobs continue to require more visual processing in increasingly restricted work space. This is particularly true in aircraft where the primary cockpit space (space in front of the pilot) is critically small and the need for visually displayed information is great. Visual displays for navigation, warning, flight control, engine monitoring, communication, weapons systems and other support systems are becoming more complex and at the same time requiring greater speed and accuracy in their detection and interpretation.

Presenting usable information in the visual periphery to be processed parafoveally (without requiring direct foveation) may permit increased visual processing loads. Parafoveally directed helmet displays, or visual displays mounted in the peripheral work space could potentially expand the usable visual work environment. A critical issue in this problem is to determine what visual information can be used in the parafoveal area and in which visual field it should be placed for the most effective and accurate processing.

The notion that the two halves of the brain differ in function is not new. Bogen (1969) reviews the literature, dating back to 1864, directed at the differential functioning of the so-called "major" and "minor" hemispheres. The thrust of much of this research has been to identify clear dichotomies between the two halves of the brain by function. Figure 1 contains a partial list of terms used to describe the dichotomous nature of human intellect and the people who used them. Figure 1 makes clear that the general trend has been to classify the left major hemisphere as verbal, logical, rational, realistic and analytic while the right brain has been classified as the less intelligent, less verbal, more impulsive, emotional and existential. The literature is replete with references to the left brain as the "major", "dominant" and "superior" hemisphere while the right is characterized as "minor", "subordinate" and "inferior" (Bogen, 1969; Harnad et. al., 1977).

The localization of functions within the brain has generally been studied by integrating the findings obtained from brain-injured patients with the more closely controlled data obtained from laboratory animals. Gur and Gur (1977) have argued that both methods of study are fraught with problems in methodology and interpretation. In human clinical data, there is little information on performance prior to injury, which makes post-trauma behavioral sequelae difficult to interpret. On the other hand, the mapping of higher cognitive functions in man through inference from animal experimentation is severely limited by the obvious discontinuities between man and lower species. This is particularly true for the study of hemispheric asymmetries in function (Levy, 1969). Recent studies of patients who have had their neocortical commissures sectioned to reduce grand mal seizures have added significantly to

FIGURE 1. Terms describing the dichotomous nature of intelligence and the people who used them.

| | LEFT BRAIN* | RIGHT BRAIN* |
|---|---|---|
| ASSAGIOLI | INTELLECT | INTUITION |
| AUSTIN | CONVERGENT | DIVERGENT |
| BATESON & JACKSON | DIGITAL | ANALOGIC |
| BLACKBURN | INTELLECTUAL | SENSUOUS |
| BRONOWSKI | DEDUCTIVE | IMAGINATIVE |
| BRUNER | RATIONAL | METAPHORIC |
| COHEN | ANALYTIC | RELATIONAL |
| DIEUDONNE | DISCRETE | CONTINUOUS |
| GUILFORD | CONVERGENT | DIVERGENT |
| HECAEN, AJURIAGUERRA, ANGELERGUES | LINGUISTIC | PRE-VERBAL |
| HILGARD | REALISTIC | IMPULSIVE |
| HOBBES | DIRECTED | FREE |
| HUMPHREY & ZANGWILL | PROPOSITIONAL | IMAGINATIVE |
| JACKSON | EXPRESSION | PERCEPTION |
| W. JAMES | DIFFERENTIAL | EXISTENTIAL |
| KAGAN & MOSS | ANALYTIC | RELATIONAL |
| D. LEE | LINEAL | NONLINEAL |
| LEVI-STRAUSS | POSITIVE | MYTHIC |
| LEVY & SPERRY | ANALYTIC | GESTALT |
| MCKELLAR | REALISTIC | AUTISTIC |
| MASLOW | RATIONAL | INTUITIVE |
| MILNER | VERBAL | NON-VERBAL |
| NEISSER | SEQUENTIAL | MULTIPLE |
| ORNSTEIN | ANALYTIC | HOLISTIC |
| C. S. PEIRCE | EXPLICATIVE | AMPLIATIVE |
| POLANYI | EXPLICIT | TACIT |
| RADHAKRISHNAN | RATIONAL | INTEGRAL |
| REUSCH | DISCURSIVE | EIDETIC |
| SCHENOV | SUCCESSIVE | SIMULTANEOUS |
| SCHOPENHAUER | OBJECTIVE | SUBJECTIVE |
| C. S. SMITH | ATOMISTIC | GROSS |
| WELLS | HIERARCHICAL | HETERARCHICAL |

*Added by authors to indicate the cerebral hemisphere typically associated with the listed intellectual capacity.

our understanding of hemispheric differences (Gazzaniga, Bogen and Sperry, 1962; Sperry and Gazzaniga, 1967). In spite of the richness of the data obtained from these "split-brain" patients, the small number of cases makes generalization to people with normal, interacting hemispheres risky at best.

In recent years, new methods have been developed to study hemispheric differences in normal, intact subjects (Gur and Gur, 1977). These techniques use the lateralized input and output techniques capitalizing on the partially separate pathways in the intact human nervous system. Perhaps the most widely used technique is to present visual information tachistoscopically from the left or right visual field, thus ensuring that it is received by only one half of the brain and therefore can only be processed to the contralateral side via the neocortical commissures. Using this research paradigm, delays in response time or increased errors have been interpreted to mean that the information has been transferred for processing to the hemisphere that is "superior" or "dominant" for the type of information. This seems to be a particularly useful research tool which has begun to yield considerable data about how the right and left hemispheres of the brain process information differently in normal subjects.

Gur and Gur (1977) have reviewed several theories which differentiate between left and right brain by their information-processing style. These theories characterize the left hemisphere as analytic, serial, digital processor while the right is an analog, parallel, Gestalt processor (Bogen, 1969; Levy, 1969; Cohen, 1973). These views of hemispheric processing styles are not mutually exclusive, nor do they reflect any basic disagreement over fact or theory. Rather, they seem to reflect differences in emphasis and perspective. What is important here is that the two halves of the brain <u>do not</u> seem to process information in the same way and that further understanding of how they differ may be used in a practical way to increase or improve the speed and accuracy of processing information.

## PURPOSE OF THE STUDY

Many of the recent tachistoscopic studies dealing with the lateralization of function in human brain have suffered from methodological problems which make interpretation of their results tenuous at best. These methodological problems, reviewed extensively elsewhere (see Berlucchi et. al., 1977), tend to fall into four general categories.

1. <u>Studies which have parafoveal stimulus exposure times of long duration</u>. Saslow (1967) has demonstrated the latency for voluntary saccadic eye movement is between 120 and 200 msec. Hemiretinal exposure times greater than this seriously degrade confidence that the stimulus was truly registered parafoveally.

2. <u>Studies which use stimuli which are not bilaterally symmetrical</u>. When a stimulus is viewed parafoveally, there is an increasing decrement in visual acuity moving from the most central to the most distal portion of the stimulus. For example, the first two letters of the stimulus word TAKE would be seen more clearly

when presented in the right visual field while the second two letters would have better acuity when viewed in the left field. Studies using this type stimulus do not account for any differences in difficulty of recognition resulting from this variance in acuity.

3. Studies which use very different stimuli to test for processing style. Many studies (reviewed by White, 1969) have demonstrated clear left hemisphere superiority for the recognition of verbal stimuli and right hemisphere advantage for the recognition of shapes, patterns, faces and nonsense figures. As Cohen (1973) suggests, these findings do not necessarily present a solution to the problem of hemispheric specialization. It is not sufficient to know that the hemispheres differ in their ability to handle particular kinds of stimuli. The more cogent question is to discover what differences exist, if any, in the manner of processing that underlies such specialization. A key study should demonstrate that the two hemispheres process the same stimuli differentially when different processing strategies are required to complete the task.

4. Studies which fail to evaluate the effect of the response mode. Most studies dealing with hemispheric differences use reaction times and error scores requiring a manual response (see White, 1969), usually with some precaution to counterbalance ipsilateral and contralateral hand responses. The use of both the preferred and non-preferred hand adds variance to the scores which may mask some of the hemispheric differences. Additionally, it may be that some other response mode having bilateral hemispheric control would be more likely to reveal hemispheric differences and would therefore be preferred over the traditional manual response.

This study has been designed specifically to evaluate differences in hemispheric processing style while attempting to rectify some of the methodological problems found in earlier research addressed above. Specifically, identical bilaterally symmetrical stimuli were presented at very brief exposure times in two tasks requiring serial and parallel processing. Additionally, two response modes were evaluated, the traditional lateralized manual response and a bilaterally controlled bite switch response.

## SECTION II

## SUBJECTS

The subjects were forty dextral males between the ages of 19 and 23. All subjects were tested for visual acuity and passed uncorrected at the 20/20 level using a standard Bausch and Lomb orthorator. Additionally, the subjects tested normal for depth perception, interocular tension and color

vision (Dvorine Pseudo-isochromatic plates) using the orthorator. All subjects were right eye dominant when tested using the line sighting procedure described by Luria (1966). The responses to a brief questionnaire indicated that none of the parents or siblings of the subjects showed any clear sinistral tendencies.

## SECTION III

## APPARATUS

The principle apparatus used in this study was a Scientific Prototype, three field tachistoscope fitted with an adjustable beam splitter head for binocular viewing. The tachistoscope was controlled by a binary logic system which automatically sequenced the stimulus slides, recorded reaction times and maintained a cumulative record of correct and incorrect responses. The three fields of the tachistoscope were controlled in a manner that permitted sequencing stimuli while maintaining constant illumination and a continuous central fixation reference dot.

The stimuli were comprised of 35 mm neutral density slides. Each slide contained a black geometric figure on a clear background. The stimulus figures were placed with their inner edge one degree to the left or right of the central fixation dot. All figures were bilaterally symmetrical, common geometric forms such as circles, triangles and rectangles and were approximately one degree of arc in height.

All testing was accomplished in a 3 m by 5 m darkened and sound-attenuated room.

## SECTION IV

## METHOD

The subjects were brought to the laboratory on two consecutive days. On the first day, they were tested for visual acuity, interocular tension, depth perception and color vision. After satisfactory completion of the vision testing, the subjects completed a brief questionnaire to establish their hand preference and the hand preference of their primary family members. The subjects were then tested for eye dominance. Only subjects with normal vision, right eye dominance and unquestioned personal and familial right handedness, were invited to return on the second day for testing.

Forty subjects were divided into four equal groups as follows:

RFMR - Right Field Manual Response
LFMR - Left Field Manual Response
RFBR - Right Field Bite Switch Response
LFBR - Left Field Bite Switch Response

The subjects in each group were tested on two experimental conditions resulting in a two factor mixed design with repeated measures across tasks (Bruning and Kintz, 1968).

Each subject was briefed on the use of the tachistoscope and the beam splitter head was adjusted for interocular distance and field focus to produce a clear image with superimposed visual fields. The subjects were then permitted to make several bite switch or manual button responses to familiarize them with the response mode. For the bite switch groups, the molded rubber mouth piece was placed so the microswitch was centered between the incisor teeth. The manual response groups were instructed to press the button with the index finger and for all practice and test sessions half the responses were made with the right hand and half with the left. Appropriate counterbalancing techniques were used with the manual response groups.

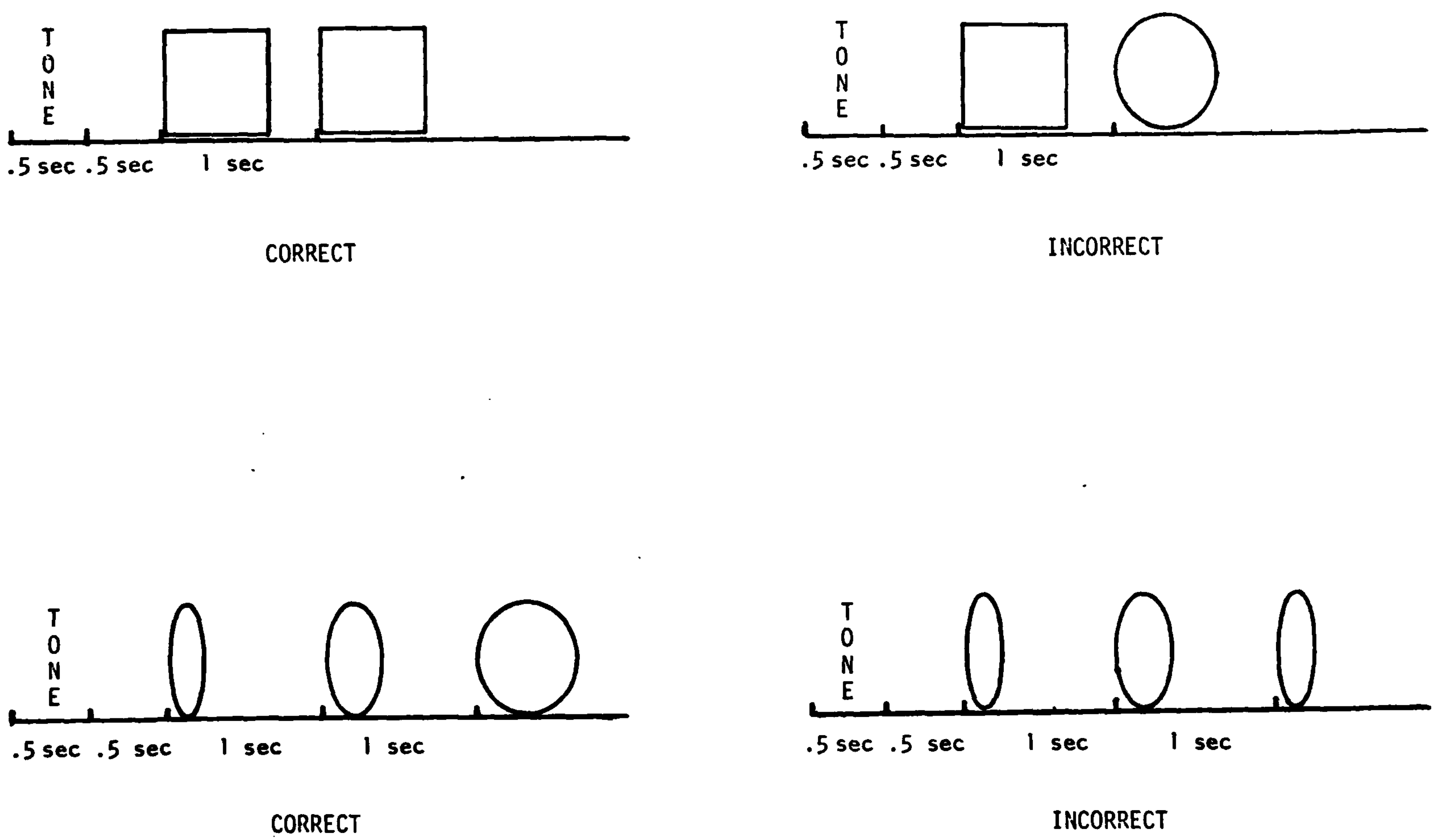
Subjects for each group were tested for basic reaction time in their assigned response mode and visual field. Twenty-four trials were given at random intervals. Each trial consisted of a .5 sec warning tone followed by a .5 sec interval and a 50 msec presentation of a hexagon figure in the appropriate visual field. Subjects were then tested on the serial and matching tasks. The order of presentation of the two tasks were counterbalanced within each group.

<u>MATCHING TASK</u>: The matching task was comprised of twenty-four pairs of test slides and five pairs of orientation slides. The subject was required to match the second stimulus figure of each pair with the first and report with a single switch closure if they were the same and a double switch closure when different. Each trial was initiated with a .5 sec warning tone followed by a .5 sec delay, 50 msec first stimulus, 1 sec delay and 50 msec second stimulus. The interval between the onset of the second stimulus and the first switch closure was used as the reaction time score. Reaction times and accuracy were automatically recorded by a digital logic system.

The subjects were instructed to fixate on the central dot and to avoid looking in the direction of the stimulus figures. The five pairs of orientation slides were used to practice parafoveal viewing (see Figure 2).

<u>SERIAL TASK</u>: The serial task was comprised of twenty-four sets of three slides each and five orientation sets. The subject was required to report if the third stimulus figure in the set completed a serial process such as an elipse becoming more rounded or an isosceles triangle becoming progressively more equilateral (see Figure 2). The timing sequence and stimulus duration times was the same as in the matching task with the exception of the addition of the third stimulus slide. Subjects responded with one switch closure for a correct sequence and with two switch closures when the process was reversed. Reaction time was measured from the onset of the third stimulus figure to the initiation of the first switch closure.

FIGURE 2. Examples of correct and incorrect stimuli and timing sequences for the matching and serial tasks.



## SECTION V

## RESULTS

The reaction times, error scores and base rate times are given in Table 1. The analysis of variance for reaction times scores indicates a significant difference between tasks ($F = 25.66$, df 1/78, $p < .001$). The overall between-group test was also significant ($F = 15.06$, df 1/38, $p < .001$). The error scores were much lower than predicted and many subjects attained perfect or near-perfect scores. It was determined that the error data violate the fundamental assumptions of a parametric test and therefore an overall analysis of variance was not done.

An analysis of the base rate data showed that the left visual field, bite switch reaction times tended to be a little slower than the other three conditions. However, none of the differences were statistically significant. For the manual response groups, a comparison was made between preferred and non-preferred hand reaction times. The preferred (right) hand tended to be slightly faster but did not approach statistical significance. An analysis was also made of ipsilateral versus contralateral manual responses. Contralateral responses were slightly faster but not significantly different from ipsilateral manual responses.

Table 2 contains the post-hoc comparisons of reaction times between the matching and serial tasks. These data show that independent of visual field and response mode, the serial task was more difficult than the matching task. The error data found in Table 3 supports this notion. The Wilcoxon Sign Test of the error data shows that for all combinations of field of view and response mode the percentage of error is significantly higher for the serial task.

Table 4 contains the post-hoc comparisons of the reaction time scores for the left and right visual field conditions. These data show that the reaction times using the manual response mode tend to be lower for both tasks when viewed in the left visual field. This difference is significant for the serial task and just falls short of significance for the matching task. For the subjects responding with the bite switch, the relationships are reversed. For both tasks, reaction times are significantly faster when the stimuli are presented in the right visual field and reach the left cerebral hemisphere first. A similar analysis was done on the error scores using the Mann-Whitney U Test (Table 5). Error scores for the bite switch response mode show a right visual field advantage similar to the reaction time data. This right field advantage is statistically significant for the serial task but is not significant for the matching task. The error data for the manual response mode show no clear trend. The error rate, especially for the matching task, was much lower than expected. As indicated above, many subjects had perfect or near perfect error scores. One can only speculate as to what the field effect would have been if the tasks were more difficult.

A comparison of the manual and bite switch response modes is made in Table 6.

TABLE 1. Reaction times in seconds, error rate scores for the matching and serial tasks by visual field and response mode. Plus base rate by visual field and response mode.

| | MATCHING TASK | | SERIAL TASK | | BASE RATE |
|---|---|---|---|---|---|
| | REACTION TIME | ERROR RATE | REACTION TIME | ERROR RATE | |
| RIGHT FIELD MANUAL RESPONSE | .983 | 5% | 1.212 | 11% | .329 |
| LEFT FIELD MANUAL RESPONSE | .750 | 5% | .886 | 14% | .343 |
| RIGHT FIELD BITE RESPONSE | .493 | 2% | .663 | 10% | .342 |
| LEFT FIELD BITE RESPONSE | .955 | 7% | 1.214 | 18% | .522 |

TABLE 2. Post-hoc comparisons of reaction times on matching and serial tasks by visual field and response mode.

| | MATCHING TASK REACTION TIME | DIRECTION OF DIFFERENCE | SERIAL TASK REACTION TIME | *t* TEST SIGNIFICANCE LEVEL |
|---|---|---|---|---|
| RIGHT FIELD MANUAL RESPONSE | .983 | $<$ | 1.212 | $t = 4.00$ df = 9 $p < .01$ |
| LEFT FIELD MANUAL RESPONSE | .750 | $<$ | .886 | $t = 3.45$ df = 9 $p < .01$ |
| RIGHT FIELD BITE RESPONSE | .493 | $<$ | .663 | $t = 3.70$ df = 9 $p < .01$ |
| LEFT FIELD BITE RESPONSE | .955 | $<$ | 1.214 | $t = 4.04$ df = 9 $p < .01$ |

TABLE 3. Post-hoc comparisons of error rate on the matching and serial tasks by visual field and response mode.

| | MATCHING TASK ERROR RATE | DIRECTION OF DIFFERENCE | SERIAL TASK ERROR RATE | WILCOXON SIGN TEST |
|---|---|---|---|---|
| RIGHT FIELD MANUAL RESPONSE | 5% | $<$ | 11% | $p < .02$ |
| LEFT FIELD MANUAL RESPONSE | 5% | $<$ | 14% | $p < .01$ |
| RIGHT FIELD BITE RESPONSE | 2% | $<$ | 10% | $p < .01$ |
| LEFT FIELD BITE RESPONSE | 7% | $<$ | 18% | $p < .01$ |

TABLE 4. Post-hoc comparisons of visual field effects for matching and serial tasks and response mode on reaction time scores.

| | RIGHT FIELD MANUAL RESPONSE | DIRECTION OF DIFFERENCE | LEFT FIELD MANUAL RESPONSE | $t$ TEST SIGNIFICANCE LEVEL |
|---|---|---|---|---|
| MATCHING TASK | .983 | > | .750 | $t = 1.53$ df = 18 $p <$ N.S. |
| SERIAL TASK | 1.212 | > | .886 | $t = 1.86$ df = 18 $p < .05$ |
| | | | | |
| | RIGHT FIELD BITE RESPONSE | DIRECTION OF DIFFERENCE | LEFT FIELD BITE RESPONSE | $t$ TEST SIGNIFICANCE LEVEL |
| MATCHING TASK | .493 | < | .955 | $t = 4.22$ df = 18 $p < .001$ |
| SERIAL TASK | .663 | < | 1.214 | $t = 3.22$ df = 18 $p < .01$ |

TABLE 5. Post-hoc comparisons of visual field effects for matching and serial tasks and response mode on error rate scores.

| | RIGHT FIELD MANUAL RESPONSE | DIRECTION OF DIFFERENCE | LEFT FIELD MANUAL RESPONSE | MANN-WHITNEY U-TEST |
|---|---|---|---|---|
| MATCHING TASK | 5% | = | 5% | N.S. |
| SERIAL TASK | 11% | $<$ | 14% | N.S. |
| | RIGHT FIELD BITE RESPONSE | DIRECTION OF DIFFERENCE | LEFT FIELD BITE RESPONSE | MANN-WHITNEY U-TEST |
| MATCHING TASK | 2% | $<$ | 7% | N.S. |
| SERIAL TASK | 10% | $<$ | 18% | $\underline{p} < .02$ |

This data show that for both tasks the bite switch response mode is quicker than the manual mode when stimuli are presented in the right visual field. When the stimuli are presented in the left visual field the relationship is reversed and the manual response mode tends to be superior to the bite switch, although this difference just fails to reach significance for the manual task. The error data in Table 7 show that the direction of differences is the same as for the reaction time data. However, none of the post-hoc comparisons for response mode reach statistical significance.

## SECTION VI

## DISCUSSION

The results clearly show that the serial task, as measured by reaction time and error scores, was significantly more difficult than the matching task. Since both tasks used very simple geometric figures, it is not likely that this effect could be attributed to the nature of the stimuli used. The serial task required recall of two previous stimuli instead of one and the cognitive process necessary to determine the correctness of the sequence was clearly a more difficult process than the same/different matching task.

The response mode effect on reaction time scores is perhaps the most interesting and potentially important finding of this study. The clear right field/left hemisphere superiority for the bite switch condition (see Table 4) cannot be attributed entirely to a simple sensory or motor advantage for this response mode. When the subjects were required to report the presence or absence of a stimulus in either visual field (see Table 1 for base rate data), there were no significant field or response mode effects. Left field stimuli tended to produce slower reaction times with the bite switch but these failed to reach statistical significance. The very large visual field differences for the bite switch conditions may reflect the combined effect of 1) a right brain disadvantage to mediate a bite switch response and 2) a left brain advantage for processing both tasks.

No physiological evidence would suggest that there would be a right brain disadvantage to initiate a bite switch response. The masseter and temporalis muscles are controlled by the mandibular branch of the trigeminal nerve which has profuse bilateral representation in the motor cortex. Therefore, it would seem unlikely that it would require left hemisphere activation to produce the biting response or that the right hemisphere could not initiate the response without first engaging the left. That there may be a left brain advantage for both tasks is supported to some degree by the error data (Table 5).

Error rates in the bite switch groups tended to be lower for both tasks when presented in the right visual field. Unfortunately, the error rates were quite low and were definitely not normally distributed within each group. The matching task was significantly less difficult than the serial task (Table 3) producing very low error rates and the Mann-Whitney U Test failed to reach statistical significance. The right field error rates for the serial task were significantly lower than the left field, suggesting a right field/left hemisphere advantage.

TABLE 6. Post-hoc comparisons manual and bite switch reaction time scores by visual field and task.

| | RIGHT FIELD MANUAL RESPONSE | DIRECTION OF DIFFERENCE | RIGHT FIELD BITE RESPONSE | $t$ TEST SIGNIFICANCE LEVEL |
|---|---|---|---|---|
| MATCHING TASK | .983 | > | .493 | $t = 1.88$ df = 18 $p < .05$ |
| SERIAL TASK | 1.212 | > | .663 | $t = 4.41$ df = 18 $p < .001$ |
| | LEFT FIELD MANUAL RESPONSE | DIRECTION OF DIFFERENCE | LEFT FIELD BITE RESPONSE | $t$ TEST SIGNIFICANCE LEVEL |
| MATCHING TASK | .750 | < | .955 | N.S. |
| SERIAL TASK | .886 | < | 1.214 | $t = 1.78$ df = 18 $p < .05$ |

TABLE 7. Post-hoc comparisons of manual and bite switch error rate scores by visual field and task.

| | RIGHT FIELD MANUAL RESPONSE | DIRECTION OF DIFFERENCE | RIGHT FIELD BITE RESPONSE | MANN-WHITNEY U-TEST |
|---|---|---|---|---|
| MATCHING TASK | 5% | > | 2% | N.S. |
| SERIAL TASK | 11% | > | 10% | N.S. |
| | | | | |
| | LEFT FIELD MANUAL RESPONSE | DIRECTION OF DIFFERENCE | LEFT FIELD BITE RESPONSE | MANN-WHITNEY U-TEST |
| MATCHING TASK | 5% | < | 7% | N.S. |
| SERIAL TASK | 14% | < | 18% | N.S. |

The reaction times for the manual response groups tend to show a left field/right hemisphere advantage for both tasks, the opposite of the bite switch groups. These differences just fail to reach statistical significance for the matching task and were significant for the serial task (see Table 4). As with the bite switch groups, these differences cannot be the result of a sensory or motor advantage for the right hemisphere. The base rate data (Table 1) show no visual field effect for the manual response mode. Since contralateral and ipsilateral hand responses were counterbalanced within each group, these results cannot be attributed to the systematic effect of more or less efficient or direct neural pathways. Additionally, since all subjects were dextrals, any physical superiority would be expected for the right field/left hemisphere responses, just the opposite of the present finding. Thus, it would appear that with a manual response there is a right hemisphere superiority for the matching and serial tasks. The error data, however, fail to support this conclusion (see Table 5).

Generally, these data would support the notion that for reaction times the processing style used and therefore the superior hemisphere for the task may be determined by the response mode required of the subject. This is not without support elsewhere. The split brain data (see Kinsbourne and Lynn, 1974 for an in depth review) have shown that when subjects are given a mental set concerning how a problem is to be solved, they are able to selectively activate the cerebral hemisphere most suited to complete the task effectively. For example, when shown chimeric faces tachistoscopically, the subjects will "see" the face in the right visual field if told that they will be asked to describe the face verbally. However, they will only see the left field half if they are told that their task will be to identify the face by selecting it from a group of other faces. These data have been interpreted to support the superiority of left brain for verbally mediated tasks and the superiority of right brain for spatial tasks.

One possible explanation for the response mode effect of this study could be that the bite switch favors the left brain which subsequently turns both tasks into verbal tasks. It has been shown that although the right brain has some language facility, the left brain is clearly superior for language, especially the naming function (see Moscovitch, 1976 for a review). Since simple geometric shapes were used in this study, the subjects could have turned the matching task into a naming task. If so, there should be a right field/left brain superiority for both tasks. Both the reaction time and error scores support this notion. It is conceivable that since the trigeminal neural pathways are so tied to verbal responses, the bite switch primes the subject to use left hemisphere activation to process the visual stimuli and make the response.

The manual response data are more difficult to understand. It was anticipated that there would be a left field/right brain superiority for the matching task and the data support this. The left visual field advantage for the serial task was not predicted and failed to support the original hypothesis. It is tempting to suggest that the manual response mode somehow forces the serial task to in some way become a spatial task, therefore favoring the right brain. This interpretation would not be in concert with the findings of many other investigators who have used the manual response in similar experimental paradigms, nor do the error data

from the present study support this notion. The resolution of this problem will require further investigation.

There is a final point that can be addressed from the results of this study. Examination of Tables 6 and 7 shows that varying the response mode may be an effective way to reduce reaction time while increasing or holding accuracy constant. The data clearly show that if it is necessary to detect and process this kind of visual information in the right field, reaction time and accuracy may be improved using a trigeminal nerve mediated response. Similarly, if the stimuli are to be presented in the left field, a manual response may be preferred.

A systematic program of investigation is needed to evaluate the human factors implications of the data presented in this report. Additional research is needed to evaluate more fully the apparent, complex interaction between response mode and brain function. Additionally, the potential application of these findings for use in sophisticated work environments deserves further study.

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